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# Employment under vertical and horizontal transfer of concentrated solar power technology to North African countries

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A B S T R A C T

The process of renewable energy technology transfer to developing countries can influence the industrialization of their economies and the reduction of their greenhouse gas emissions. There are current plans to deploy large-scale solar and wind capacities in the North Africa countries, including the Mediterranean Solar Plan on the public side and the Desertec Industrial Initiative on the private side. We analyse both plans from a technology transfer perspective, drawing a distinction between vertical transfer – in which intellectual property and manufacturing capacity remains in industrialized countries – and horizontal transfer, in which manufacturing and development skills shift to the developing countries. We find that horizontal technology transfer, when 40% and more of all components are manufactured locally, would bring significantly higher number of job-years to North Africans than vertical technology transfer, and that the greatest number of jobs are induced in the service industries. However, the total job creation will still not provide jobs to all unemployed people in the entire region. A case study of Morocco suggests, however, that employment effects could be important for any country that gains a disproportionate share of new investment. Recent policy developments in North Africa show that national governments started to take into consideration possibilities and benefits of horizontal technology transfer by launching plans of industrial development and introducing the rule of local compensation, which foresees a share of components for large-scale projects to be manufactured locally and by North African enterprises.



**Contents**



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## 1. Introduction

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) the level of $CO_2$ emissions need to decline globally by 50% by 2050 in order to avoid dangerous climate impacts, with reductions of 80% in industrialized countries and regions, such as Europe [28]. The development of large solar generation of electricity for domestic use in North Africa, and its export to Europe via high voltage direct current (HVDC) transmission lines, can be one of the options to reach such ambitious targets [7].

According to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, industrialized countries should transfer renewable energy technologies to developing countries, in order to help them limit and decrease their $CO_2$ emissions. At the same time, analysts view the transfer of renewable energy technologies as an important element of socio-economic development, helping developing countries to modernize [37]. The current rate of technology transfer appears too slow to meet either objective, and hence would need to increase [19].

Several questions remain open regarding actual benefits of technology transfer programs, which specific case studies can address. In this paper, we examine the case of concentrated solar power (CSP) development in North Africa to identify differences in impacts from scenarios with varying degree of local manufacturing of components and supply chains of CSP industries. We are looking at local versus non-local job creation due to vertical technology transfer, in which intellectual property and manufacturing capacity remains in industrialized countries, and horizontal technology transfer, in which manufacturing and development skills shift to the developing countries. We analyse this in the context of recently proposed CSP growth scenarios for the region, such as the Mediterranean Solar Plan, which foresees 20 GW of renewable energy capacity by 2020 [11,9].

## 2. Background

### 2.1. Technology transfer

Until the second half of the 20th century countries closely guarded their technology, seeing it as a source of military and economic power [21]. However, the process of transferring renewable energy technologies (RET) from industrialized to developing countries became seen as an essential step in the global reduction of greenhouse gas emissions ([41,19]). Policy-makers included RET technology transfer as an essential element of the UNFCCC and the Kyoto Protocol.

Classically technology transfer is regarded as a large-scale public investment based on foreign technology and loans from multilateral organizations. These loans have lower interest rates and longer repayment period than commercial loans. In this context, technology transfer takes two forms [25]. The first involves the manufacturing and sale of technology in host countries, while the ownership remains in foreign hands. This is known as *vertical technology transfer*. In this case, new technologies are given via investment to a target group, but there is no transfer of knowledge or skills to local manufacturers. Most often a large multi-national corporation sets its factory in a developing country, with the goal of decreasing costs of operation. In order to minimize the risk of losing intellectual property, management and technical staff are nationals of developed countries, the general workforce is cheap local labour, and the whole enterprise is owned and operated by the multinational company.

Since vertical technology transfer includes only minimal knowledge transfer and domestic capacity building, some scholars claim that it is of little value, and suggest that there needs to be *horizontal technology transfer* [39]. Under horizontal technology transfer a joint venture between a foreign and a local company is established, including technical and business training. This is a more lengthy process but it allows embedding of technology within local population and economy, which can eventually allow local partners to fund, manufacture, operate and maintain new the technologies themselves [15]. Horizontal technology transfer is more preferable to local economies as skills and knowledge are built up in developing countries but makes it more difficult for foreign companies to protect their design and to control the quality of products manufactured by local partners.

The IPCC definition labels technology transfer as a process “covering the flows of know-how, experience and equipment, for mitigating and adapting to climate change among different stakeholders such as governments, private-sector entities, financial institutions, non-governmental organizations and research/educational institutions”, and this favours the horizontal approach [27]. The process can happen through joint ventures, foreign direct investment (FDI), government assistance programs, direct purchases, joint research and development programs, franchising and sale of turnkey plants [27].

Both vertical and horizontal technology transfer involve both private and public partners. The participation of private companies is essential, since they own the rights to most of the renewable energy technologies. Hence, private companies shall be willing to invest in projects, even though the risks are often high in developing countries [23]. The public sector plays a key role through the creation of an adequate institutional framework and industrial market, as well as a favourable investment climate, all of which can reduce the perceived risks [24]. To signal their reliability, national governments often state targets for deployment of different technologies.

### 2.2. Scenarios for scaling up CSP in North Africa

Today the worldwide installed capacity of CSP plants in operation has reached 2550 MW [34]. The biggest share of the installed capacity is in the United States (85%), followed by Spain (15%). During the last year the European and American solar energy companies started to expand significantly their business to key developing countries, such as the Middle East and North Africa (MENA) region, China, and India.

Currently there are three CSP power plants in construction or operation in Algeria (Hassi R´mel), Morocco (Ain Beni Mathar) and Egypt (Kuraymat). Each of these plants has 20 MW of solar capacity. They all are hybrid projects, generating energy from both gas and solar heat sources. All three CSP plants were developed using the financing from the World Bank and almost all components and equipment for these plants were imported. Projects in the planning stage are much more ambitious. The largest volumes of projects are currently at the planning or operation stage in Morocco (250 MW), followed by Algeria (240 MW), Egypt (110 MW) and Tunisia (50 MW). Additionally, 500 MW CSP power station Noor I is currently under construction in Morocco. This is a large-scale parabolic trough CSP plant in the province of Ouarzazate. The first phase includes construction of 300 MW, during the second phase additions MWs will be added. The finalization of the first phase is planned by the end of the year 2015 (Fig. 1).

There have been several studies demonstrating the feasibility and costs of scaling up of CSP technology in the North African region, coupled with high voltage direct current (HVDC) lines to Europe, entailing transmission losses of only 10–15–15% ([6,42]). The economic potentials for solar energy in the Sahara deserts are much higher than all estimates for local and European

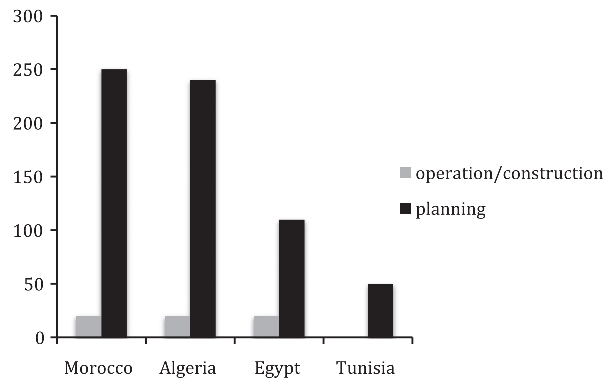


**Fig. 1.** CSP capacities in MENA region in planning or operation (MW).
*Source*: REN21 [35]

energy demand. Solar electricity imports have potential to be scaled up to 700 TWh/y by 2050. Furthermore, there are large opportunities for cost reductions of CSP electricity [42]. In the North African region, where solar irradiance is most favourable, this can result in solar electricity costs falling to 0.05€/kWh (0.07 $/kWh) before 2025, at which point they will be competitive with coal and gas, even in the absence of a carbon price or a direct subsidy [43].

This research has supported the development of several scenarios and plans for developing CSP capacities in North Africa over the coming decades. In 2008, the European Union launched the Mediterranean Solar Plan (MSP). This plan foresees deployment of 20 GW of renewable energy capacities in the Mediterranean region, mainly solar and wind, by 2020 [11]. Built on the experience of the Barcelona process and integrates its institutions and policies, it includes reinforcement of power grid interconnections and technology transfer in the Mediterranean region. The plan foresees implementation of large-scale CSP plants with capacities up to 200 MW as well as small commercial CSP plants with capacities below 50 MW [36].

From the side of private investors, a consortium of private companies launched the Desertec Industrial Initiative (DII) in 2009. Located in Munich, the partners include several solar and wind companies, banks, insurers, and transmission operators. The long-term goal of DII is to satisfy about 15% of the Europe's electricity demand by 2050 with power produced from sun and wind in the deserts of North Africa [8].

The World Bank supports deployment of CSP in five North African and Middle East countries such as Morocco, Algeria, Tunisia and Egypt as well as in Jordan. The goal of the World Bank is to scale up the deployment of CSP technology to about 1 GW over a 3–5 year time frame. In December 2009 the Clean Technology Fund of the World Bank approved financing of €543 million ($750 million) to deployment of CSP technology in five above-mentioned countries. This investment is a part of an investment plan to mobilize an additional €3.5 billion ($4.85 billion) from other sources [4].

### 2.3. *Estimates of employment benefits*

Between 1970 and 2001 the population of the MENA region grew up from 173 million to 386 million people. The fertility rate per woman declined from 7.0 births in 1960 to 3.6 births in 2001, which can be explained by different factors, but mainly by educational programs, socio-economic development and increased rate of employment among women [38]. Nevertheless, the MENA region has one of the fastest growing populations in the world, averaging 2% growth per year, or nearly 7 million new people, and partly because of its young age structure – more than 30% of population are below the age of 15 – it is expected that the MENA region population will double again by 2050 [45].

Within the MENA region, North Africa in particular is characterized by one of the highest unemployment rates in the world. Only 45.3% of population of active age is employed, while 42% of all employed are working poor, earning less than 2€ ($2.8) a day; the total unemployment rate increased by 25% between 1997 and 2007. The unemployment rate among young people is the highest in the world, and indeed 25% of the world's unemployed youth resides in the region [48]. Only 20% of all women in working age have employment, although many of them are not seeking employment: those officially registered as unemployed constituted 32.2% of the working age female population in 2008.

Generally, the expectations regarding creation of employment opportunities under the renewable energy transfer are optimistic [12]. The projections rest on the extrapolation of past job growth to future growth scenarios. Between 1990 and 2008, for example, the deployment of wind industry capacity increased by a factor of almost 50, creating almost 200,000 new jobs in the year 2008 worldwide ([16]). Plausible future scenarios describe renewable energy accounting for 48% of power generation by 2050 (IEA, Blue Map Scenario, 2010). Only at the US the SunShot initiative as a target to support roughly 290,000 new solar-related jobs by 2030 and 390,000 new solar-related jobs by 2050 [46]. Typical of reports from lobbying and industrial organizations are sentences such as “we are currently at the beginning of the area of clean-technology jobs, which will be the greatest opportunity for wealth and global competitiveness since the advent of computer and Internet” [5]. There is one estimate that globally up to 2 million people will be employed in the CSP sector alone by 2050 ([14]).

While there have been many estimates of “green job” creation in general, most have focused on Europe and North America, with a dearth of studies focusing on developing countries' employment benefits, and no robust studies at all looking at North Africa [44]. This reflects the fact that the bulk of documented growth of green jobs has taken place mostly in industrialized countries, and only recently in fast growing the developing countries like China, Brazil, and India.

While there have been studies of job creation from wind power, only two have focused on employment from CSP, as this technology contributed less to global electricity production even until now. First, the National Renewable Energy Laboratory (NREL) in the United States estimated employment impacts of CSP deployment in California. In 2002, NREL had developed the Jobs and Economic Development Impact Model (JEDI), using an input–output framework to evaluate the employment impacts of wind power deployment. In 2008, they adapted this to parabolic trough technology, calling it JEDI-CSP. The study found that 94 permanent jobs came from 100 MW of CSP (56 of which are indirect). 3000 permanent jobs came from installing 4000 MW. The DOE SunShot Vision study (2012) estimates 1 on-going job per MW for operations and maintenance. The main assumption is that the balance of plants equipment as well as all construction, installation and engineering works are provided by domestic suppliers and manufactured in California ([31]). The European Solar Thermal Electricity Association (ESTELA) conducted the second employment study of CSP, evaluating employment impacts in the Mediterranean region. The estimates of ESTELA are based on interviews with industrial stakeholders, and does not include the more robust methods found in the NREL analysis. The results project that 20 GW of CSP capacity deployment in the Mediterranean region will create up to 200,000 direct job-years by 2020 in the construction of installations and the manufacturing of components. The

ESTELA study assumed that 50% of components necessary for CSP installations will be manufactured in Europe and 50% in North Africa [13].

Because ESTELA is a lobbying organization and its results were based on methods less transparent that the NREL study, there remains a need for robust and credible analysis of gross jobs from CSP in North Africa, as we are estimating here the jobs supported by a particular project. Such analysis, including the relative benefits of the vertical and horizontal technology transfer, could be an essential input into future negotiations on the terms of technology deployment between European and North African governments. To address this need, we adapted the JEDI-CSP model to the North African investment context by changing input parameters on investment costs, multipliers and North African wages, and applied it to the growth scenarios for CSP that have been developed for the region.

## 3. Methods

The goal of this research was to estimate direct, indirect and induced employment from both horizontal and vertical CSP transfer to the North African region. To estimate employment effects we use an input–output (IO) model. This type of model is a representation of national or regional economic accounting that records the way industries trade with one another and produce flows of products and services. Those flows are registered in a matrix, simultaneously by origin and by destination [33]. IO models are one of three classes of models that economists typically use to study the employment effects of particular policies of projects, the other two being computable general equilibrium models (CGE) and system dynamic models (SD).

The accuracy of results strongly depends on the choice of model approach and the availability of reliable data. In general, IO models have lower data requirements than CGE models or SD models, while other advantages of include their ability to utilize national accounts data, their relatively detailed sectoral resolution, their transparency, and their ease for analysing multiple scenarios. While CGE and SD models have several advantages, their greater data requirements can make them difficult or impossible to apply in developing economies, like economies of countries of the North African region, where availability of data is limited. For this reason we have chosen to use an IO framework.

The main approach of an IO model can be described with the following equation, which incorporates all domestic impacts along the entire supply chain:

$$(I–A)-1y=x,$$

where, $I$ is the unity matrix, $A$ is the matrix of the domestic technology coefficients reflecting the input share of sector one in the output of sector two, $y$ is the scalar of demand per sector. The inverse of $(I–A)$ is known as the Leontief Inverse. Finally, $x$ is the scalar of the direct and indirect production values per sector. Based on $x$ it is possible to derive the economic indicators such as GDP, tax, employment, imports, as a linear transformation of the production value per sector.

The advantage of this model in comparison to analytical mixed qualitative and quantitative methods, on which the ESTELA study relied, is that it not only calculates the numbers of direct job-years, but also allows an estimation of induced job-years using local North African multipliers in addition to revised cost parameters and wages.

As a method the IO models were often used to provide input to policy-making process and thus are highly relevant for such tasks as estimation of employment processes [20]. The use of Input–Output multipliers is particularly suitable for the evaluation of national and regional industries and the impact assessment of broad policy instruments at the regional and national level [10].

One job-year is a full-time equivalent job for one year, so job-years mainly refer to temporary jobs. The concept of “job-years” actually means that these are temporary jobs and are created for one year only. The number of years shall be assumed in the plant life to calculate for permanent jobs.

Direct employment refers to the total number of persons employed in an organization and belongs to a certain sector. Indirect employment is employment throughout the chain of production and it refers to people contracted by a firm to provide intermediate components or products or services to an organization. According to this understanding, under direct jobs we mean employment in construction, management and operation of the power plants. Under indirect jobs we mean employment in manufacturing of components in CSP industries, such as in manufacturing of steel for the solar plants, and in services related to the project. Induced jobs are created from spending of people employed directly or indirectly by the solar manufacturing industries or services. Below (Fig. 2) we show the graphical representation of the concept “job-years”, assuming that the plant will be constructed during 5-year period, which is an average for the CSP projects [22].

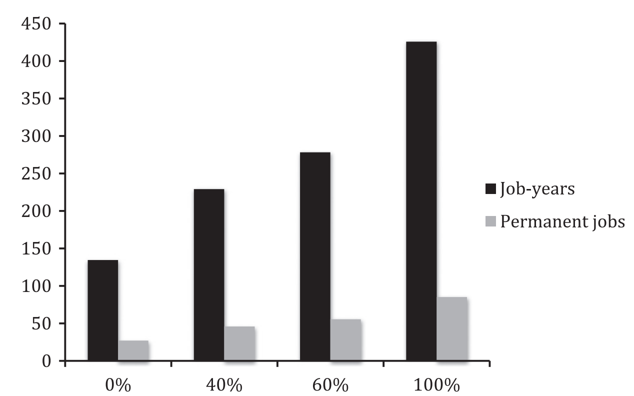


**Fig. 2.** Graphical representation of job-years and permanent jobs (thousands) assuming the 5-year duration of the project.
*Source*: authors.

First, we started with an input–output model developed for CSP by the National Renewable Energy Laboratory. This, to our knowledge, is the only existing model developed explicitly to capture employment effects from CSP [40]. We do not develop our own model as the model with an explicit focus on CSP was already developed by NREL. We base our modelling work on two assumptions, which we take from NREL studies of construction processes of CSP plants and logistic issues [32]. We assumed that the share of materials for construction such as concrete rebar, equipment, roads and site preparation is constant with 95% production from local areas. Second, we assumed that labour for field erection is mainly done by local people, relying on 80% local labour for site-work and infrastructure, field erection, support structures, piping, and electrical works. Plant workers include field technicians, administration and management. Economic impacts during operating years represent impacts that occur from plant operations and expenditures. The analysis does not include impacts associated with spending of plant profits.

To be able to estimate induced employment we calculate the North African multipliers on the basis of the Social Accounting Matrix (SAM) for North African economies. We assume that there are no economies of scale in production or factor substitution and the doubling of the level of production will not necessary lead to

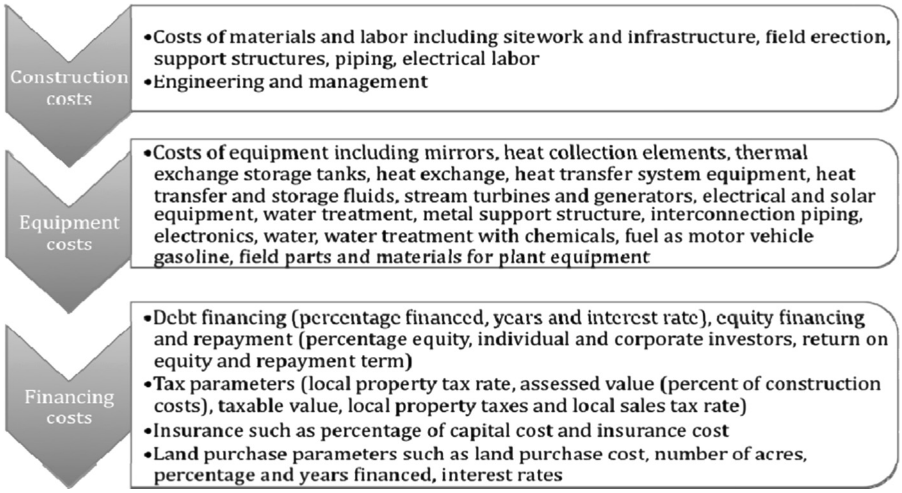


**Fig. 3.** Groups of costs parameters.
*Source*: Climate Investment Funds [3].

**Table 1**
Assumptions for some of the investment parameters.
*Source*: World Bank (2009), IEA [19].

| Materials (subtotal) in thousands | Labour (subtotal) in thousands | Construction (subtotal) in thousands | Equipment (subtotal) in thousands | Other (subtotal) in thousands |
|---|---|---|---|---|
| 32,427€<br>44,789$ | 16,260€<br>22,458$ | 48,690€<br>67,252$ | 123,387€<br>170,427$ | 14,884€<br>20,558$ |

the doubling of all the inputs and outputs. Therefore, our I/O table will not necessary have linear relations between inputs and outputs from different sectors and between outputs and final demand. We apply domestic investment matrix, which includes such categories as final consumption and gross fixed capital formation. To be able to calculate multipliers we first calculate technical coefficients to convert initial monetary values into ratios. This coefficient shows us the rate at which inputs are transformed into outputs. Finally, we derive our output multipliers by using the Leontief inverse matrices, which shows us the induced requirements in terms of industries outputs of a production unit of a given industry's output [26].

A variety of methods exists to quantify the macroeconomic effects from investment into renewable energy projects. These range from basic approaches to sophisticated modelling, which involves predictions, inherent uncertainties and numerous assumptions. Our choice for the model in our research is explained by such factors as suitability to our research interests and capability to provide robust answer to our research questions and data availability. We adapt our model from the National Renewable Energy Laboratory's Jobs and Economic Development Impacts (JEDI) Concentrating Solar Power (CSP) model, which was designed to allows users to estimate economic development impacts from CSP projects in the United States. The advantages of starting with the JEDI platform is that it provides a well-established set of parameters for CSP plant analysis, with only those parameters associated with project development in the United States needing to be changed to fit the local context.

JEDI constructs profiles of investments during different phases of the project cycle, and allows demonstration of employment and economic impacts that are likely during construction and operation phases, and allows one to differentiate between local and non-local job-creation activities. Local spending results from using local labour, such as concrete pouring jobs, services such as engineering, legal or design, materials and other components. The user can replace these default values with project-specific information, such as costs and expenditures, financing, taxes, and local share of spending [17].

Fig. 3 shows the sets of investment parameters that we then adapted to North African conditions. The entire JEDI model is based on United States standard industry codes, and US Bureau of Labour Statistics and other data. To obtain a result for North Africa, we replace the US multipliers (which are US state-based) with the North African multipliers, which according to scientific evidence vary between 1.5 and 4 [2].

We derive data on investment parameters from several sources, such as fact-finding missions of SolarPaces, which is an international network to bring experts from around the world to discuss development of concentrating solar power systems to the North African countries, from databases and publications of the International Energy Agency and the World Bank (World Bank, 2009; IEA, [19] (Table 1).

More detailed explanation of the investment parameters is in the Annex of the paper (Table A1).

Second, we examined the sensitivity of the number of direct, indirect and induced job-years generated by the CSP industry according to the share of components produced in the North African countries. We examine four scenarios:

- When all high and medium technology components are produced outside North Africa,
- When 40% of components are manufactured locally,
- When 60% of components are manufactured locally,
- When all 100% of components are manufactured in North African countries

Two latter scenarios are quiet high as currently the majority of components are manufactured outside the area and the 100% would be probably unrealistic for the middle-term future. One can describe horizontal technology transfer as taking place when the

share of components and equipment manufactured locally is higher than 40%, a result of technology specific modelling conducted by the German government (Trieb et al., 2009). The preliminary assessment conducted by the World Bank shows that potentials of North African countries to manufacture components of the CSP plants are high. The basic infrastructure work, like installation of solar fields and construction of power blocks and storage systems would account for roughly 17% of total CSP investment. This work as well as mounting structure in case when local companies can adapt manufacturing processes to produce steel and aluminium components with high quality, can be carried out by local people. The manufacturing of more complex components will require joint ventures with European companies or foreign direct investment to install new production facilities in the North African region [4].

Third, we focused analysis of particular growth scenarios on the country of Morocco. We chose Morocco because of its ambitious plans to deploy CSP capacities, and its ideal location to serve European energy markets [47]. In November 2009, Morocco launched a €7 billion ($9.6 billion) solar plan, foreseeing deployment of five CSP plants between 2015 and 2020 with a total capacity of 2000 MW [29]. One of these, already planned to be cited in Ouarzazate, will have a capacity of 500 MW, and will be an important step towards energy security of the country, which is currently heavily reliant on imported fossil fuels. The Ouarzazate will be the first plant developed under the CSP investment plan of the World Bank, with the Climate Technology Fund and the African Development Bank being two other potential contributors. It is expected that this project will create employment opportunities in CSP related industries [4]. Existing electrical connections between Morocco and Spain would allow as well exports of electricity to Europe. The interconnections exist since 1997 and connect the electricity grid in the north of Morocco to the grid in the south of Spain across the Strait of Gibraltar. The capacities of these grids are 1400 MW.

## 4. Results

### 4.1. Plant based estimates

According to the adjusted parameters we were able to calculate the number of job-years in direct and induced employment generated per 100 MW of CSP capacity deployed in the region, following the four different scenarios regarding the share of components manufactured locally. Table 2 shows the results of how many job-years will be created if all 100 MW of capacity will be deployed during one year.

These results allow us to reach three important conclusions. First, the number of job-years created in case when all components are manufactured locally exceeds the number of job-years created when all components are manufactured abroad by more than a factor 3 (614 job-years comparatively to 200 job-years). Second, in the case when all components are manufactured locally 100 MW of CSP capacities in North Africa create more job-years than 100 MW of CSP capacities in California (614 job-years comparatively to 455 job-years). Third, the number of induced jobs is as well higher (4666 job-years comparatively to 3500 job-years), likely because of the lower level of wages in North Africa compared to California.

**Table 2**
Number of job-years created per 100 MW of CSP capacities.
*Source*: authors.

| Job-years per 100 MW | 0% | 40% | 60% | 100% |
|---|---|---|---|---|
| Direct jobs in planning and construction | 74 | 83 | 146 | 151 |
| Indirect jobs in materials and components | 126 | 240 | 284 | 463 |
| Total direct and indirect jobs | 200 | 323 | 430 | 614 |
| Induced jobs | 1520 | 2455 | 3268 | 4666 |

### 4.2. Scenarios

Next, we scale up the number of job-years generated per 100 MW up to 20 GW of CSP capacity. We assumed that all 20 GW were just CSP capacities and that they were deployed in the North African countries, but we examined two scenarios for technology transfer. Vertical transfer is based on our 0% components scenario in the previous section, while horizontal transfer is based on our 100% scenario. We compare the results of our calculations of direct jobs-years with results of ESTELA and NREL, and the indirect employment estimates with those of NREL alone (Fig. 4).

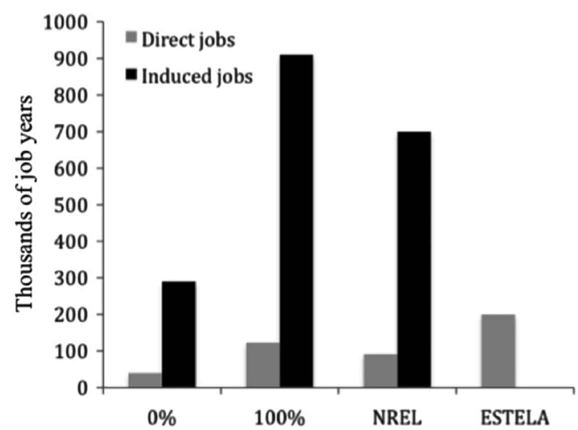


**Fig. 4.** Scaled up comparison.
*Source*: authors.

In case of horizontal technology transfer, when all components are manufactured locally, the deployment of MSP, namely of 20 GW of CSP capacities, will create 122,600 direct job-years and more than 900,000 induced job-years. In case of vertical technology transfer, when all components are manufactured abroad, MSP will bring to North African only 40,000 direct job-years and less than 300,000 induced job-years. The estimations of NREL are between our 0% and 100% scenarios and assume that if all components are manufactured locally the deployment of 20 GW of CSP capacities will bring 91,000 job-years in direct employment and 700,000 job-years in induced employment. The estimations of ESTELA are substantially higher, saying that MSP will create 200,000 direct job-years.

Next, we extrapolated these results to the plans of the Desertec Industrial Initiative (DII), namely to generate electricity from CSP that will be equal to 15% of the Europe's electricity demand by 2050, which translates to 700 TWh/y of electricity. In this case, vertical transfer would create 265,000 job-years in North Africa in case when all components are produced outside the region and 430,000 jobs-years if the share of components were 40%. This would result in between 2 and 3 million jobs-years respectively in induced employment, assuming that multiplier effects remain constant in the case of such large-scale development. Horizontal transfer would lead to 575,000 job-years in direct employment if more than a half of all components are produced in the region, and 820,000 job-years if North Africans produce all components. If the multiplier effects were still constant, this could lead to 6 million induced job-years by 2050. We also assume the existing learning

rate and economies of scale for CSP technology (Williges et al., 2010).

The total, direct, indirect and induced, job-years created by the DII scenario would be two million job years if 40% of component manufacturing were local, and rising to six million job years if it were eventually 100%. If this were spread over 20 years, which, based on the evidence from scientific literature, we assume would be the length of the project (DLR, 2005), it would lead to annual employment of between 100,000 and 300,000. Under vertical technology transfer, fewer than 100,000 jobs would be created. These numbers compare with total unemployment of 7 million persons in the North African region.

### 4.3. Moroccan case study

We compared existing statistics for Morocco with our results on CSP employment, in order to estimate what CSP deployment consistent with the MSP would mean for the Moroccan labour market. In 2008 the Moroccan population reached 32 million people, of whom only 33% were economically active (Moroccan National Statistics, 2012 [30]). We base our analysis on four assumptions: that all 20 GW of CSP capacities will be deployed in Morocco; that all CSP installations will be constructed over the course of a five year period; that the rate of horizontal transfer will be the highest when all components are manufactured locally.

Four economic sectors can be affected directly by deployment of CSP capacities. These are mining and quarrying, manufacturing, electricity, gas and water supply and construction. Manufacturing is by far the largest employer among these sectors, employing 1.2 million people, while leaving 166 thousand trained workers unemployed. Construction employs another 0.8 million, leaving 108 thousand trained workers unemployed. Electricity, gas and water supply employs 45 thousand people, while mining and quarrying employ 42 thousand people, with less than 4000 trained workers unemployed between the two sectors [18]. These are estimations for the total number of trained unemployed people. Our model suggests that deployment of 20 GW capacity would bring direct employment ranging between 40 and 125 thousand job-years, depending on whether vertical or horizontal technology transfer takes place. This could relieve, but not eliminate, unemployment in these four sectors.

The induced effects from CSP deployment, by contrast, would again be substantially greater. Looking to the structure of the Moroccan economy, it could take place in the following sectors: trade, hotels and restaurants, transport, telecommunications, financial services, and real estate. The increased government revenues from CSP could also influence employment in public administration, defence, and education. In 2008, the largest share of the population had employment in trade, hotels and restaurants (1.7 million), followed by the public sector, with 1.5 million, while transport and telecommunications employed 424 thousand, and the real estate and financial sectors employed 168 thousand people combined. The number of officially registered unemployed in these sectors in 2008 reached 270 thousand, with just over half of these in trade, restaurants and hotels.

Deployment of 20 GW of CSP capacity in Morocco would not only bring employment opportunities, but would also bring restructuring to the Moroccan economy of horizontal technology transfer were to take place. As Fig. 5 shows, the induced job-years generated by CSP deployment would meet or exceed the number of currently unemployed trained workers in the relevant economic sectors. Even scaling these down by a factor of five – given the five year construction schedule – means that induced employment from CSP deployment could approach total unemployment in the service sector. This would likely lead to some of those listed as unemployed in sectors such as manufacturing to jump over into more service-oriented activities.

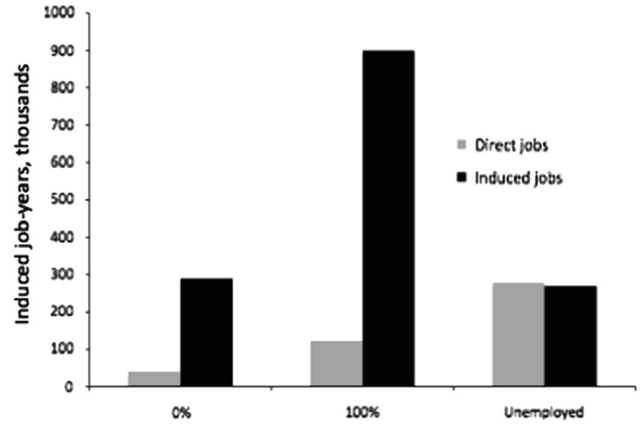


**Fig. 5.** Employment created in case of horizontal and vertical technology transfer and the number of unemployed where creation of direct and induced job-years is possible.

We examined a case where the entire 20 GW of the MSP were located in Morocco, due to its comparative advantage in terms of proximity for transmission and a pro-active government. However, we also need to take into consideration that 20 GW is an optimistic assumption as the current Moroccan policy targets foresee deployment of 2 GW of solar capacity by 2020.

On the one hand, this suggests that North African countries could have an incentive to compete against each other for CSP deployment. On the other hand, it suggests that any country that wins such a contest would also have to ensure that it was prepared for an eventual end to the CSP construction boom, once European import needs were met.

## 5. Conclusion

Our results allow us to make three conclusions. The first one is that the existing estimates of interest-driven organizations such as ESTELA are optimistic but comparatively to other regions such as California the number of job-years created from investment into CSP in North Africa will be higher because of the difference in labour costs. Second, that CSP deployment could begin to make difference for North African economies, but mainly from horizontal technology transfer, when a significant share of components higher than 40% is manufactured in the region. Third, that the results would be different if a disproportionate share of CSP deployment takes place in a single country, such as Morocco. The number of jobs created under horizontal technology transfer could be substantially enough to push the country towards a more service-oriented economy, closer in structure to those of industrialized countries.

It is important to note that any assumption of 100% local production seems unrealistic in the short run. Currently the major manufacturers of components for CSP industries are located outside North Africa, but the probability exists that they could move to North Africa to be able to reduce transport and labour costs. A benchmark example could be the aerospace or auto industries in Europe that use components produced in North Africa. Several of these components have similar components to CSP industries. These include manufacturing of glass, mechanical engineering and electrical equipment. The opportunity exists that the auto and aero suppliers to Europe will be able to diversify their production to CSP components. Nevertheless, these processes take time.

The limitations of this study lay in the scope of our research work. The main scope was to analyse potential economic benefits of CSP component manufacturing industries in the North African region in terms of direct, indirect and induced employment. It was out of the scope of this study to conduct a more detail analysis of manufacturing processes of components. Therefore, we were able to give a general evaluation of the number of new job-years created to be able to compare employment effects under vertical and horizontal technology transfer scenarios. Other limitations are connected with our assumptions that in case of Morocco all 20 GW will be constructed in a five-year period. But at the current stage of research the uncertainty is too high about the speed of construction of CSP installations and we needed these results for comparison of impacts from vertical and horizontal technology transfer under conditions of an existing country.

This study could have implications for international, regional and national policies dealing with the issues of technology transfer. It shows that horizontal technology transfer could have significant impacts in terms of induced employment, especially if particular countries gain a disproportionate share of new projects. This will allow to provide employment to most of officially unemployed people as well as to empower women who are currently not officially registered as unemployed and do not participate actively in the income generating activities and to decide emigration problems.

Additional research is needed on the process of CSP transfer to the North African region itself. There is need for multidisciplinary study evaluating the perceptions of stakeholders regarding the horizontal and vertical technology transfer processes, and the feasibility of both options in the region. Behavioural and policy research needs to focus on the motivations of countries that are leaders in manufacturing of renewable energy components to participate in the technology transfer. It is also important to focus on motivation of private companies that are leaders in research and development of CSP, and whether they will participate in technology transfer without harming their balance sheets and returns to shareholders. The successful examples from other regions and countries could be studied in this respect, such as the experience of China in horizontal technology transfer. Secondly, feasibility studies could evaluate local existing conditions for horizontal and vertical CSP technology transfer, including local capacities to produce high quality manufacturing components and existing scientific and industrial base. Such research would assess potentials for CSP manufacturing industry in the North African region, including cost reduction potentials for key CSP components and establishing of a roadmap for development of local CSP manufacturing.

Recent developments in the North African region show that national governments have started to take into considerations possibilities and benefits of horizontal technology transfer. For example, Morocco launched a new plan for industrial development with the goal to make it as a driver of economic growth. The major objective of this plan is to implement strategies, which would allow to accelerate industrialization of the country. There are hopes that this acceleration will lead to creation of half a million job-years, fifty per cent of which should be created by foreign direct investment and an increase of the share of industry in the Moroccan GDP from 14%, as it is by today, to 23% by 2020. In light of this development the government is introducing the rule of “local compensation”, which means that a share of components for large-scale projects shall be provided and is reserved for the Moroccan enterprises. This government decision is driven by the hope that such rule will allow developing the local value chains in Morocco (L’Economiste, N° 4247, 2014/04/03). There is evidence of implementation of this rule for wind projects but not yet for CSP. For example, in the area of wind energy, Morocco is progressing in implementation of the rule for industrial compensation. However, the implementation of this rule varies significantly in different regions dependently on the stage of the project realization, starting at 0% for the park of Abdelkhalek Torrés (50 MW) in Tétouan, which was a first project, to 5% at the level of the project in Amohdoul in Essaouira (60 MW), to almost 16% for the project in Tanger 1 (140 MW). In some cases the share of components manufactured locally was even greater then required by the rule of compensation. In the park of Taza it is 30% and in the project of Tarfaya (300 MW) it is almost 34% [1].

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## Annex

Table A1 shows as an example of input parameters detailed construction costs as well as operation and management costs for the CSP Trough Plant Hassi R’Mel, constructed in Algeria in 2010. We assume the solar direct normal radiance of 6.64 kWh/m$^2$/day, the project size of 400 MW, the solar field aperture area 359.000 m$^2$ and the plant capacity factor of 40%. We also provide data for financial and tax parameters, all input data are in dollars, money value of 2006. For our calculations we use investment parameters for different CSP through plants in the North African region.

The data below are an example of the highest share, which is typical to horizontal technology transfer. Here we assume 100% of

**Table A1**
CSP trough plant: project data summary.
*Source*: International Energy Agency (IEA), [19].

| Construction costs | Cost | Local share |
|---|---|---|
| Materials | | |
| Construction (concrete rebar, equip, roads and site prep) | $42,060,000 | 100% |
| Materials subtotal | $42,060,000 | 100% |
| Labour | | |
| Site-work and infrastructure | $880,000 | 100% |
| Field erection | $8,700,000 | 100% |
| Support structures | $4,364,000 | 100% |
| Piping | $5,346,000 | 100% |
| Electrical | $1,798,000 | 100% |
| Labour subtotal | $21,088,000 | |
| Construction subtotal | $63,148,000 | |
| **Equipment costs** | | |
| Mirrors | $16,581,000 | 100% |
| Heat collection elements | $15,369,000 | 100% |
| Thermal energy storage tanks | $0 | 0% |
| Heat exchangers | $0 | 0% |
| Heat transfer system equipment | $0 | 0% |
| Heat transfer and storage fluids | $16,600,000 | 100% |
| Steam turbines and generators | $1,840,000 | 100% |
| Misc. electrical and solar equipment (pumps, motors, drive, etc.) | $2,843,000 | 100% |
| Water treatment | $9,300,000 | 100% |
| Metal support structure | $21,823,000 | 100% |
| Interconnection piping | $28,575,000 | 100% |
| Electronics and controls | $47,100,000 | 100% |
| Balance of plant | $0 | 0% |
| Equipment subtotal | $160,031,000 | |

**Table A1** (*continued* )

| Construction costs | Cost | Local share |
|---|---|---|
| **Other costs** | | |
| Freight and transportation | $500,000 | 50% |
| Engineering and project management | $11,753,000 | 0% |
| Owner costs (not included above) | $7,051,000 | 50% |
| Other subtotal | $19,304,000 | |
| **Subtotal project costs** | $242,483,000 | |
| Sales tax (materials and equipment purchases) | $42,000,000 | 100% |
| **Total project costs** | $284,483,000 | |
| | **Cost** | **Local share** |
| **Personnel** | | |
| Operations | $2,478,882 | 100% |
| Administrative | $1,335,730 | 100% |
| Power plant maintenance | $1,601,107 | 100% |
| Field maintenance | $2,224,243 | 100% |
| Personnel subtotal | $7,639,962 | |
| **Materials and services** | | |
| Water | $327,342 | 100% |
| Water treatment (chemicals) | $329,704 | 50% |
| Misc. services | $829,870 | 100% |
| Fuel (motor vehicle gasoline) | $75,090 | 100% |
| Field parts and materials and plant equip | $5,671,071 | 50% |
| Misc. supplies and equipment | $2,115,336 | 50% |
| Materials and services subtotal | $9,348,412 | |
| Debt payment (average annual) | $14,185,256 | 0% |
| Equity payment – individuals | $0 | 100% |
| Equity payment – corporate | $6,045,909 | 0% |
| Property taxes | $2,844,830 | 100% |
| Sales tax | $603,447 | 100% |
| Insurance | $1,422,415 | 0% |
| Land purchase | $34,868 | 100% |
| Land lease | $0 | 100% |
| Total annual operating and maintenance costs | $42,125,098 | |
| Other parameters | | |
| **Financial parameters** | | **Local Share** |
| **Debt financing** | | |
| Percentage financed | 60% | 0% |
| Years financed (term) | 20 | |
| Interest rate | 10% | |
| **Equity financing** | | |
| Percentage equity | 40% | |
| Individual investors (percentage of total equity) | 0% | 100% |
| Corporate investors (percentage of total equity) | 100% | 0% |
| Return on equity (annual interest rate) | 6% | |
| Repayment term (years) | 30 | |
| **Tax parameters** | | |
| Local property/other tax rate (percentage of taxable value) | 1.0% | |
| Assessed value (percentage of construction cost) | 100.0% | |
| Taxable value (percentage of assessed value) | 100.0% | |
| Taxable value | $284,483,000 | |
| Local property taxes | $2,844,830 | 100% |
| Sales tax | 7.75% | 100% |
| **Insurance** | | |
| Percentage of capital cost | 0.50% | |
| Insurance cost | $1,422,415 | 0% |
| **Land purchase parameters** | | |
| Land purchase cost (per acre) | $2,000 | |
| Number of acres | 299 | |
| Percentage financed | 90% | 100% |
| Years financed (term) | 30 | |
| Interest rate | 6.5% | |
| Land purchase cost | $598,333 | |
| **Land lease parameters** | | |
| Land Lease cost (per turbine) | $0 | |
| Land lease (total cost) | $0 | |

the local share for components manufactured in the region for almost all investment parameters.

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